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# Application of Foundry Waste Sand In Manufacture of Concrete

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***ABSTRACT:*** *Metal foundries use large amounts of sand as part of the metal casting process. Foundries successfully recycle and reuse the sand many times in casting process. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as "foundry waste sand." Like many waste products, foundry sand has beneficial applications to other industries.*

*Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. Foundry sand can be used in concrete to improve its strength and other durability factors. Foundry Sand can be used as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.*

*In the present work, experimental investigations were performed to evaluate the comparative study of the properties of fresh & hardened concrete containing ferrous & non-ferrous foundry waste sand as fine aggregate replacement. Fine aggregates were replaced with four percentages of foundry sand. The percentages of replacements were 0, 10, 20, & 30% by weight of fine aggregate & tests were performed for all replacement levels of foundry sand for M20 grade concrete at different curing periods (7 & 28 days).*

***Keywords –*** *Compressive strength, Ferrous, Non-ferrous, Split tensile strength, Water absorption.*

## 1. INTRODUCTION

Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of ferrous and non-ferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. It is a by-product from the production of both ferrous and non-ferrous metal castings.

The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their molding and casting operations.

The raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. The sands form the outer shape of the mold cavity. These sands normally rely upon a small amount of bentonite clay to act as the binder material. Chemical binders are also used to create sand "cores".
Depending upon the geometry of the casting, sands cores are inserted into the mold cavity to form internal passages for the molten metal. Once the metal has solidified, the casting is separated from the molding and core sands in the shakeout process. In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as by-product, new sand is introduced, and the cycle begins again. Although there are other casting methods used, including die casting and permanent mold casting, sand casting is by far most prevalent mold casting technique. Sand is used in two different ways in metal castings as a molding material which focuses the external shape of the cast part and as cores that form internal void spaces in products such as engine blocks. Since sand grains do not naturally adhere to each other so binders must be introduced to cause the sand to stick together and holds its shape during the introduction of molten metal into mold and cooling of casting.

Kolhapur is recognized by World Industrial Sector for highly casting productions. In Kolhapur district near around 300 foundry industries are there thus ranking first in Maharashtra state. Foundries in Kolhapur use much of silica sand for casting processes & waste generated from these foundries are about 700-1000 tonne/day. This solid waste is used for dumping near river banks. Foundry industry is declared as a „Red Category Industry for discharging hazardous substance in the environment, But due to high treatment cost, foundry industries are not much interested to invest on safely disposal of waste sand.

If we see the present scenario of foundry industries & waste disposal methods adopted by them, it is clear that in future, problems related to disposal of spent foundry sand are going to become severe. As per present disposal practices sand which is dumped on baron land can not be recovered. If it can be used for other purposes such as in construction materials, flow filling, ceramic industry, bricks (Hollow blocks), embankment construction & repair, mineral wool products etc., it will get profit & production cost of the industry where sand is to be reused will get reduced & by this way we can achieve a sustainable disposal of spent foundry sand.

## 2. LITERATURE REVIEW

Several researchers investigated the use of WFS in various civil applications. Billie J. Lindsay and Terry J. Logan [1] reported agricultural Reuse of Foundry Sand, normally used in blended top soil for residential, landscaping, industrial, or reclamation purposes and as a rooting zone for sports turf. T.R.Naik et.al.[2] reported that excavatable flowable slurry with desirable physical properties can be manufactured using foundry sand as a replacement for fly ash up to 85%. Tara Sen and Umesh Mishra [3] reported the use of FWS in village road construction. Evaggelia Petavratzi and Scott Wilson [4] reported the use of foundry sand into facing bricks as filler was successful at small substitution rates (primary sand substitution at 2.5 and 5%). Alberta C. Carpenter and Kevin H. Gardner[5] studied the use of Industrial By-Products in Urban Roadway Infrastructure. J. P. de Koff, B. D. Lee and R. S. Dungan [6] studied **a**melioration of Physical Strength in Waste Foundry Green Sands for Reuse as a Soil Amendment. Kae-Long Lin, Ching-Jung Cheng, Ang Cheng and Sao-Jeng Chao [7] reported use of recycled waste foundry sand as raw materials of cement additives. Robert S. Dungan, Jong-Shik Kim, Hang-Yeon Weon, April B. Leytem.[8] studied the characterization and composition of bacterial communities in soils blended with spent foundry sand. Sayeed Javed,[10] investigated the use of Waste Foundry Sand in Highway Construction. M B Mgangira,[11] carried out assessment of the influence of the proportion of waste foundry sand on the geotechnical engineering properties of clayey soils. Kwanho Lee, Jaeyoon Cho, R. Salgado and Inmo Lee,[12] carried the Retaining Wall Model Test with Waste Foundry Sand Mixture Backfill.

Not much work has been reported on the use of WFS in concrete and concrete related products. Some researchers have reported on the work concerning to the various application and methods used for testing of the concrete made by foundry sand which are,

T.R. Naik et al. [13] conducted an investigation evaluate the performance of foundry by-products in concrete & masonry products. Based on the test results they concluded that, (a) The addition of foundry sand caused a decrease in concrete workability. (b) Compressive strength of concrete decreased slightly due to the replacement of regular coarse aggregate with foundry slag. However, compressive strength observed for both 50 and 100 percent slag mixes were appropriate for structural uses. (c) The modulus of elasticity of the 100 percent slag mix was the highest of all the three mixes evaluated. (d) All the masonry blocks made with 35 percent new/used foundry sands passed ASTM requirements for compressive strength, absorption and bulk density.

Khatib et al.[14] investigated **s**ome mechanical and fresh properties of concrete containing waste foundry sand (WFS). With reference to the properties investigated, they reported that (a) There is systematic loss in workability as the foundry sand content increases which was found by observing the percentage decrease in slump with increase in WFS. (b) All the mixes (with and without WFS) show an increase in strength with curing time. (c) The compressive strength of concrete also decreases with increasing amounts of WFS. This decrease is systematic. (d) The control mix shows the least water absorbed and generally the water absorption increases as the WFS in the concrete increases. (f) The shrinkage increases as the WFS in the concrete increases and this increase is systematic.

Gurpreet Singh and Rafat Siddique [15] performed experimental investigations to evaluate the strength and durability properties of concrete mixtures, in which natural sand was partial replaced with (WFS). Test results obtained shown that, (a) Concrete mixtures made with WFS exhibited higher compressive strength than control concrete. From the results, it was found that 28 day compressive strength increased by 8.25%, 12.25%, 17% and 13.45% for mixtures M-2 (5%WFS), M-3 (10% WFS), M-4 (15% WFS) and M-5 (20% WFS) respectively than control mixture M-1 (0% WFS). Comparative study of compressive strength at 28 and 91 days indicate that % increase in compressive strength decreases with the increase in WFS content at 91 days in comparison to 28 days, it was decreased by 7% to 1.98%. (b) Splitting tensile strength of concrete mixtures increased with the increase in WFS content. Splitting tensile strength of control mixture M-1 (0% WFS) was 4.23 MPa at 28 days. It was increased by 3.55%, 8.27%, 10.40% and 6.38% of M-2 (5% WFS), M-3 (10% WFS), M-4 (15% WFS) and M-5 (20% WFS) respectively. Higher value of splitting tensile strength was observed at 15% WFS.
(c) Ultrasonic pulse velocity test was performed on concrete containing 0%, 5%, 10%, 15% and 20% of WFS at the age of 28 and 91 days. Test results shown that USPV value increased with the increase in waste foundry content in concrete mixtures and it also increases with age. USPV value for concrete mixture containing WFS was found more than control concrete mixture M-1 (0% WFS).

Saveria Monosi, Daniela Sani and Francesca Tittarelli,[16] investigated the properties of mortars and concretes containing different dosages of used foundry sand (UFS) as partial replacement of sand in both fresh and hardened conditions. According to the obtained test results, they concluded that, (a) UFS reduces the workability when added as natural sand replacement (at same w/c); higher amount of superplasticizer is required in order to maintain the same workability. The control mortar sample with w/c equal to 0.50 requires an addition of 0.5% by cement weight, while mortars containing UFS need an addition up to 1.8%. Similarly, concrete mixture containing UFS needs a superplasticizer dosage. (b) Fresh mixture unit weight (UNI EN 12350-6) and entrapped air content (UNI EN 12350-7) do not point out any relevant differences with and without foundry sand. (c) Despite the absolute value of compressive strength, the negative influence ascribed to the presence of UFS in reducing the compressive strength seems greater when lower w/c is adopted. Although the absolute value of the compressive strength is high at low w/c ratio, as usual, it achieves negligible advantages when w/c is lower than 0.50.

### 2.1 Research Significance

Use & Recycling of ferrous & non ferrous metal casting industry waste is important issue in today s world. WFS sand is the major waste of the metal casting industry used as byproduct. In this work FWS is used as partial replacement of fine aggregate in concrete in order to investigate & compare the effect of ferrous & non-ferrous WFS on the strength & durability properties.

## 3. MATERIALS AND METHODS

### 3.1 Materials

ISI mark 43 grade cement (Brand- Ultratech ) was used for all concrete mixes. The cement used was fresh and without any lumps. Testing of cement was done as per IS:8112-1989. The sand used for the experimental program was locally procured and conformed to grading zone III as per IS: 383-1970. Crushed stone aggregate with a maximum particle size of 12.5mm and 20mm was obtained from local quarry & was used as coarse aggregate. Normal sand was used as fine aggregate in all concrete mixes. Ferrous foundry sand was procured from K & K Foundries, MIDC, Shiroli, Dist - Kolhapur & non ferrous foundry sand from Dynamic Metal Works, Five Star MIDC Kagal, Kolhapur. Sieve analysis of all fine aggregates & coarse aggregate was carried in the laboratory. The w/c ratio was kept constant for all the mixes. Superplasticizer Rheobuild SP1–300ml/Bag of cement was used to maintain the flow, workability of plain concrete in the form of slump. Mix proportion of M20 grade was used to produce the mixes.

### 3.2 Mixing and test procedures

A careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. The concrete mixture was prepared by rotating drum concrete mixer. The proportions of fine aggregates were fed into the drum first and mixed thoroughly. After that coarse aggregates were added to it. Superplasticizer as per requirement was added to required quantity of water separately in different containers. Then water was added carefully so that no water was lost during mixing. Cubical moulds of size 150mm*150mm*150mm were casted for compression strength testing and cylindrical moulds of 150 mm diameter & 300 mm length were casted for split tensile test. The moulds were cleaned & oiled properly before every pouring. The concrete was filled in the moulds in three layers, each layer being tamped with tamping rod. Also the vibrations were given by putting the cubes on the chasis of the mier. The specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition and were covered with plastic sheet to prevent moisture loss due to evaporation. After that these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing. At the end of every curing period, the samples were taken out of curing tank and were tested.

## 4. EXPERIMENTAL RESULTS & DISCUSSIONS

### 4.1 General

Various properties of concrete incorporating foundry sand at various replacement levels with fine aggregate were studied, results were compared and checked for compressive strength, split tensile strength & water absorption of foundry sand mix with ordinary mix.

### 4.2 Fresh concrete properties

Table 1 shows the fresh properties of concrete such as slump, temperature & density with and without FWS addition. Slump is observed to decrease with the introduction of FWS. This could be attributed to the high water absorption of FWS. Density of mixtures with FWS was observed to be less than that without FWS.

**Table 1 : Fresh concrete properties of mixes with and without FWS.**

| Mixture No. | M1 | M2 | M3 | M4 | M5 | M6 | M7 |
|---|---|---|---|---|---|---|---|
| Cement | 340 | 340 | 340 | 340 | 340 | 340 | 340 |
| Natural Sand | 857 | 771 | 685 | 599 | 771 | 685 | 599 |
| Ferrous WFS % | 00 | 10 | 20 | 30 | -- | -- | -- |
| Ferrous WFS (Kg/m³) | 00 | 86 | 172 | 258 | -- | -- | -- |
| Non-Ferrous WFS % | 00 | -- | -- | -- | 10 | 20 | 30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Non-Ferrous WFS (Kg/m³) | 00 | -- | -- | -- | 86 | 172 | 258 |
| Coarse Aggregate 12.5mm | 571 | 571 | 571 | 571 | 571 | 571 | 571 |
| Coarse Aggregate 20mm | 857 | 857 | 857 | 857 | 857 | 857 | 857 |
| W/C ratio | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |
| Water content (Kg/m³) | 184 | 184 | 184 | 184 | 184 | 184 | 184 |
| Super plasticizer (Ltr./m³) | 2.04 | 2.04 | 2.04 | 2.04 | 2.04 | 2.04 | 2.04 |
| Fresh concrete density (Kg/m³) | 2762 | 2661 | 2741 | 2645 | 2732 | 2631 | 2657 |
| Slump (mm) | 40 | 30 | 30 | 20 | 00 | 00 | 00 |
| Air temperature (ºC) | 25 | 25 | 24 | 26 | 29 | 25 | 30 |
| Concrete Temperature (ºC) | 26 | 26 | 25 | 28 | 31 | 26 | 31 |

### 4.3 Hardened Concrete Properties
### 4.3.1 Compressive Strength
In this research the values of compressive strength for different replacement levels of ferrous foundry sand contents (0%, 10%, 20% and 30%) and non ferrous foundry sand contents (0%, 10%, 20% and 30%) at the end of different curing periods (7 & 28 days) are plotted in fig. 1, which show the variation of compressive strength with fine aggregate replacements at different curing ages. It is evident from Fig. 1 that compressive strength of concrete mixtures with 10%, 20% and 30 % of foundry sand as sand replacement was higher than the control mixture (M-1) at 7 days age and the strength was maximum at 20% replacement level for both types of sands.

Compressive strength results of concrete mixtures with and without FWS sand at the age of 28 days shown that concrete mixtures made with ferrous FWS exhibited lower compressive strength than control concrete for 10% & 20% replacement level and it was almost equal to that of control mix for 30% replacement level. Whereas Compressive strength of concrete mixtures made with non ferrous FWS exhibited almost equal value as that of control concrete for 10% replacement level and goes on reducing for 20% and 30% replacement level.

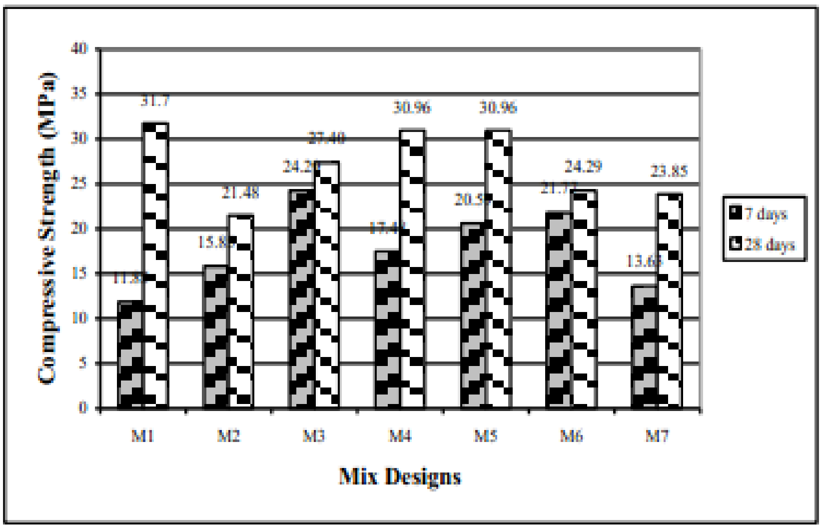
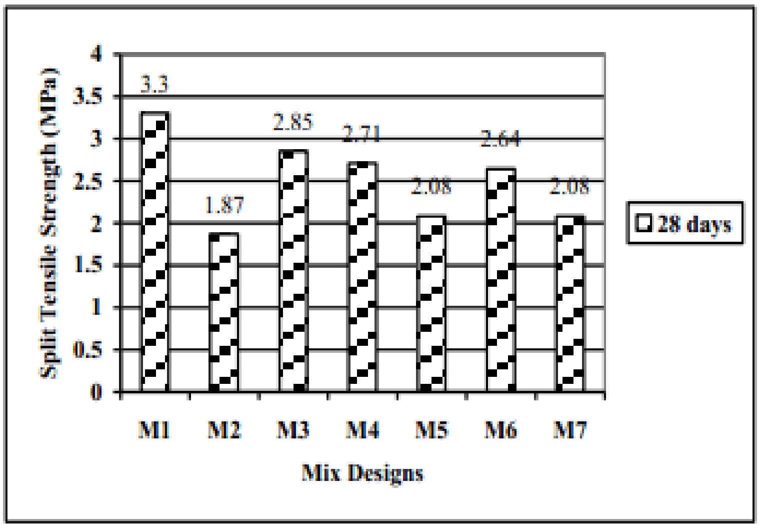



Fig.1: Compressive strength of concrete containing WFS after 7 & 28 days of curing

### 4.3.2 Split Tensile Strength
Splitting tensile strength of concrete mixtures made with and without FWS were determined at the ages of 28 days and test results are shown in Fig. 2

**Fig.2: Split tensile strength of concrete containing WFS after 28 days of curing**.




Splitting tensile strength of control mixture M-1 (0% FWS) was 3.3 MPa at 28 days. There was decrease in strength to 1.87 MPa for M-2 (10% Ferrous FWS), 2.85 for for M-3 (20% Ferrous FWS), 2.71 for M-4 (30% Ferrous FWS) and 2.08 for M-5 (10% Non-Ferrous FWS), 2.64 for M-6 (20% Non-Ferrous FWS) and 2.08 for M-7 (30% Non-Ferrous FWS) respectively. Higher value of splitting tensile strength was observed at 20% ferrous WFS and at 20% non ferrous FWS. So it is evident that both the foundry waste sands gives maximum splitting tensile strength at 20% replacement level.

### 4.3.3 Density, Water absorption & Porosity:

Water absorption & porosity are important indicators of the durability of hardened concrete. Reduction of water absorption & porosity can greatly enhance the long term performance & service life of concrete in aggressive service environments. Decreased porosity also benefits the compressive & flexural strengths of concrete, as a fundamental relationship exists between porosity and strength of solids. Table 2 shows the results of bulk density (dry), bulk density (after immersion) and water absorption test results for hardened concretes with and without foundry waste sand at 28 days of age. No appreciable effect of FWS on water absorption of mixes was observed.

**Table 2: Density (hardened concrete), water absorption and porosity:**

| Mixture No. | Bulk Density (Dry) (Mg/mm³) | Bulk Density (After Immersion) (Mg/mm³) | Absorption % |
|---|---|---|---|
| M1 | 2.56 | 2.61 | 1.91 |
| M2 | 2.54 | 2.59 | 1.93 |
| M3 | 2.62 | 2.65 | 1.13 |
| M4 | 2.53 | 2.58 | 1.93 |
| M5 | 2.55 | 2.59 | 1.54 |
| M6 | 2.6 | 2.65 | 1.88 |
| M7 | 2.56 | 2.61 | 1.91 |

## 5. CONCLUSIONS

Following conclusions are drawn from this investigation.

1. The fresh concrete data shows that addition of both foundry waste sands gives low slump mainly due to the presence of very fine binders, so these mixtures require high superplasticizer dosage in order to maintain a good workability.
2. Compressive strength at 7 days of both ferrous & non ferrous mixtures increases as compared to the ordinary mix. Maximum increase was observed with 20% FWS of both types of sand. However 20% ferrous WFS addition gives more value of compressive strength than 20% non ferrous FWS addition.
3. Compressive strength at 28 days increases with the increase in ferrous FWS and at 30% addition, it gives almost same strength as that of ordinary concrete whereas 10% addition of nonferrous FWS gives same strength as ordinary concrete and goes on decreasing for higher percentages of replacement.
4. Split tensile strength gives maximum values with 20% FWS for both types of sands. However ferrous WFS gives slightly more strength than nonferrous FWS.
5. Inclusion of both ferrous & non ferrous FWS gives dense concrete at 20% addition.

6. Water absorption is minimum with 20% ferrous FWS & with 10% non ferrous FWS. Whereas mixture with 10% non ferrous FWS gives least water absorption value
7. Both ferrous & non ferrous FWS can be suitably used in making structural grade concrete.

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